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A vertical gustiness recorder for use with a captive balloon.

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AIR MINISTRY

METEOROLOGICAL RESEARCH COMMITTEE

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Summary

A description is given of an instrument which has been designed and used to measure vertical gustiness in the form of inclination and mean speed of the wind, from a position on the cable of a captive balloon. A light wind vane and a 'windmill' anemometer were used as sensing heads with automatic partial compensation for balloon movements. The data and reference signals were relayed by electric cable to ground level and recorded on a single channel recorder. Some sample records taken at heights up to 4,000 ft. are presented.

Introduction

In connection with certain diffusion experiments a requirement arose for an instrument to measure vertical gustiness at heights beyond the reach of masts or towers. It was therefore necessary to design the instrument in a form suitable for suspension from a captive balloon. To use the near maximum operational height of the balloon, the weight of equipment together with any connecting electric cable had to be kept low compared with that of the tethering cable. The weight of the instrument could have been reduced by using a hot wire anemometer but this would have required heavy, low-resistance cables. Also a hot wire instrument is fragile, the output is nonlinear, and the calibration frequently unreliable. The use of radio for transmission of data was considered as a means of reducing the loading of the balloon, but was rejected because of the complexity of the equipment.

The requirement was met by the use of a light-weight vane responding to variations in wind inclination, its angular position being registered electrically. To eliminate the effect of the changing angle of the tethering cable, the instrument was effectively suspended, a principle previously used by J.H. Field and R. Warden[*] for a mechanical instrument used to investigate air currents in the lee of the Rock of Gibraltar. The instrument also incorporated a 'windmill' type anemometer for speed measurements and an arrangement for reference signals which served as a check on the functioning of the instrument and provided a calibration.

Instrumental Details

The inclination vane, A (Fig.1), was mounted to respond to vertical wind fluctuations and positioned the sliding contact, B (Fig.2), of a low friction potentiometer, C. This potentiometer formed two arms of a bridge network, (Fig.3), which gave an output voltage directly proportional to the vane inclination. The vane, and anemometer, D, were mounted at either end of an arm, E, which was maintained in the cross-wind vertical plane by suspension

/from

from the nose of the control vane arm, F. Freedom of the control arm to rotate axially through 40° ensured that the mounting of the sensing heads remained in the along-wind vertical plane when the balloon cable, G, moved out of this plane. Damping of any tendency to oscillatory motion of the arm, E, was effected in the along-wind plane by a balanced air piston-cylinder, H, and in the cross-wind plane by oil dampers, J.

The assembly, (Fig.1), including a box, K, containing circuit components and a 3 volt battery was mounted on the balloon cable by means of split bearings, L, and was free to turn into the mean wind direction (horizontal) under the action of the control vane, M.

The inclination vane, of aerofoil section (6 in. x 3 in.) was constructed of balsa wood and tissue paper, doped and waterproofed, and with the 6 in. long dowel support weight ¼ oz. This vane was balanced by a counterpoise weight, N, and electrical connection to the sliding contact was made via a hair spring, P. Response time (90%) when operating in a wind speed of 5 m./sec. was approximately 0.1 sec., increasing to approximately 0.3 sec. in a 3 m./sec. wind.

A step-cam operated switch, Q, built in at the rear centre of the anemometer was used to alternate the output voltage of the potentiometer with a reference voltage taken from a tapped resistor across the bridge, (Fig.3). This reference voltage was equivalent to an inclination of -20°. The cam was driven by the anemometer rotor through fine gears with a reduction ratio of 200:1 so that the switch was operated at every 100 metres of air flow for approximately 4 metres of air flow. The output from the bridge circuit thus indicates the wind inclination for 96% of the time and for the remainder gives pulses which calibrate for wind inclination and which enable the wind speed to be determined.

Ground Equipment

The instrument was connected to the recorder by 5000 ft. of light-weight cable (26 s.w.g. conductors, 0.2 in. outside diameter) via a low gain amplifier. The comparatively high input impedance of the amplifier, (Fig.4), enabled linearity of the bridge output voltage (directly proportional to inclination) to be maintained. The amplifier was balanced, with two directly coupled stages and with negative feedback (cathode of 6SN7 to screen of EF37). The feedback reduced the maximum voltage gain to 26 db. but linearised the input/output characteristic and stabilised the gain.

As linearity was maintained throughout the measuring and recording systems and the 0° and -20° equivalent voltages (zero and reference pulse ht.) were known, subsequent calibration of the inclination vane was unnecessary. Sensitivity could be altered at will by adjustment of the 10,000 ohm variable resistor which interconnected amplifier and recorder, so that the reference pulse was of suitable height in relation to the scale of the chart. The value of this resistor was about 8,800 ohm for 20° = 1mA (recorder resistance = 2,400 ohm) and this maintained rapid response of the recorder where otherwise it would have been reduced considerably by the damping action (low impedance) of the cathode follower output stage. Drift within the amplifier was low, and, with the required degree of attenuation, caused negligible zero drift in the recorder.

The sample records shown in Fig.5 and 6 were taken with the 'Super-responsive' Everett Edgecumbe 'Inkwell' recorder, which had a range of 2.5 -0 - 2.5 mA over a chart width of 10 cm. Measured response time (for 90% response) when used in conjunction with the above D.C. amplifier was 0.2 sec., with 50% attenuation at a frequency of 10 c/sec. Chart speeds of 1, 3 and 12 in./min. were available.

/Use

Use in the Field

The gustiness recorder has been used on diffusion experiments carried out over a period of two months. The captive balloon used for supporting the instrument was a Mark 10 kite balloon with a cable tension of 4-5 cwt. at low level. The maximum height quoted for this balloon, using standard tethering cable, and without any additional load, was 5,000 ft. The weight of the instrument was 7 lb. and the electric cable used weighed 15 lb. per 1,000 ft. Portability and operation of the instrument were satisfactory and no adjustment for drift or change of sensitivity was necessary after the initial warming up period (about 5 min.) of the amplifier. Compensation for changes in the angle of the tethering cable of the balloon was satisfactory but measurement of height variations was found to be necessary as this introduced a significant spurious component into the inclination record in strong gusty winds. These measurements were made by frequent observations on the instrument using a theodolite. An example of the vertical component due to balloon movement is shown plotted on the -30° line of Fig.6a. Fig.5a and b, and Fig.6b and c also contain some spurious component due to the vertical movement of the instrument but this was small due to the low wind speed (3-5 m./sec.) in the case of Fig.5, when the tethering cable was near vertical, and due to the steady nature of the wind in the cases shown in Fig.6b and c.

The heights quoted on the sample records are length of cable paid out, actual heights above ground being lower by not more than 3% in these cases. Values of mean temperature difference ($\overline{\Delta T}$) are for 23 ft. - 4 ft. above ground level and also in Fig.6 for a 200 ft. interval about the point of gustiness measurement.

Reference

* Field, J.H. and Warden, R. 1933 Met.Office, G.M. 59.

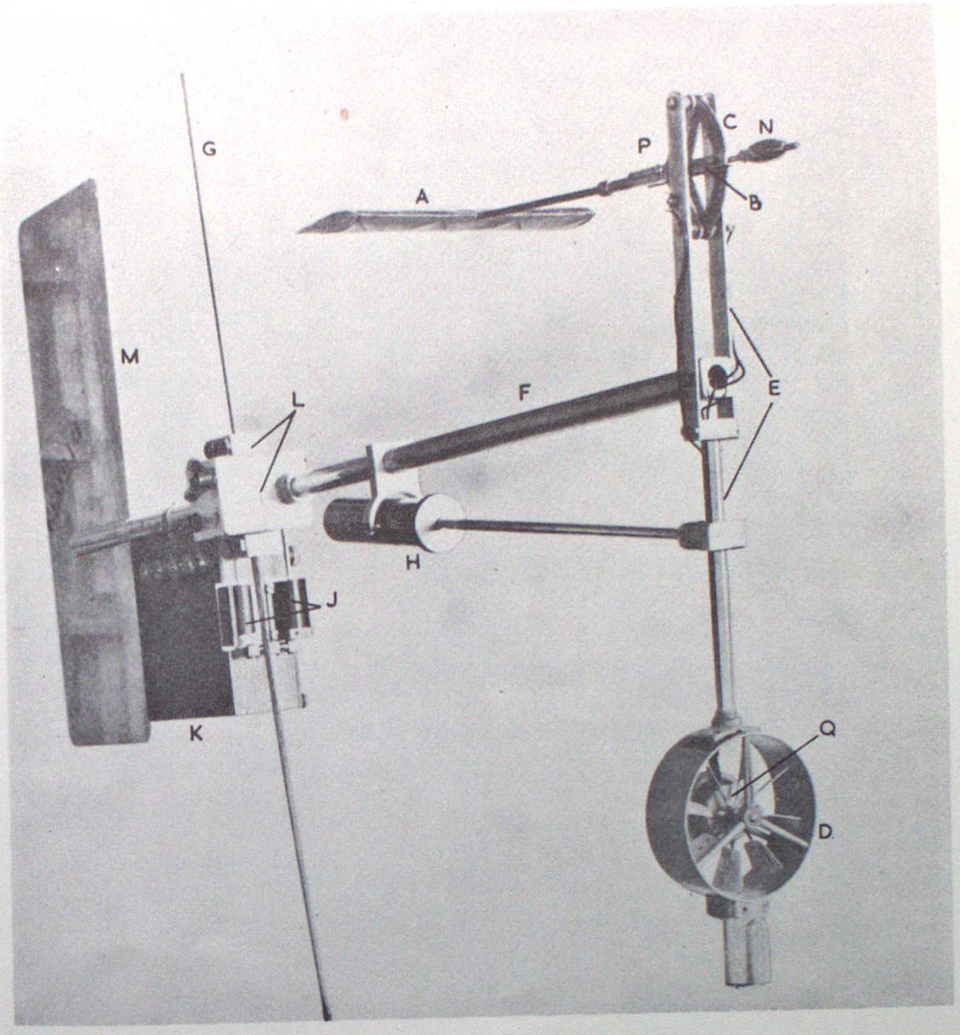


FIG. 1.

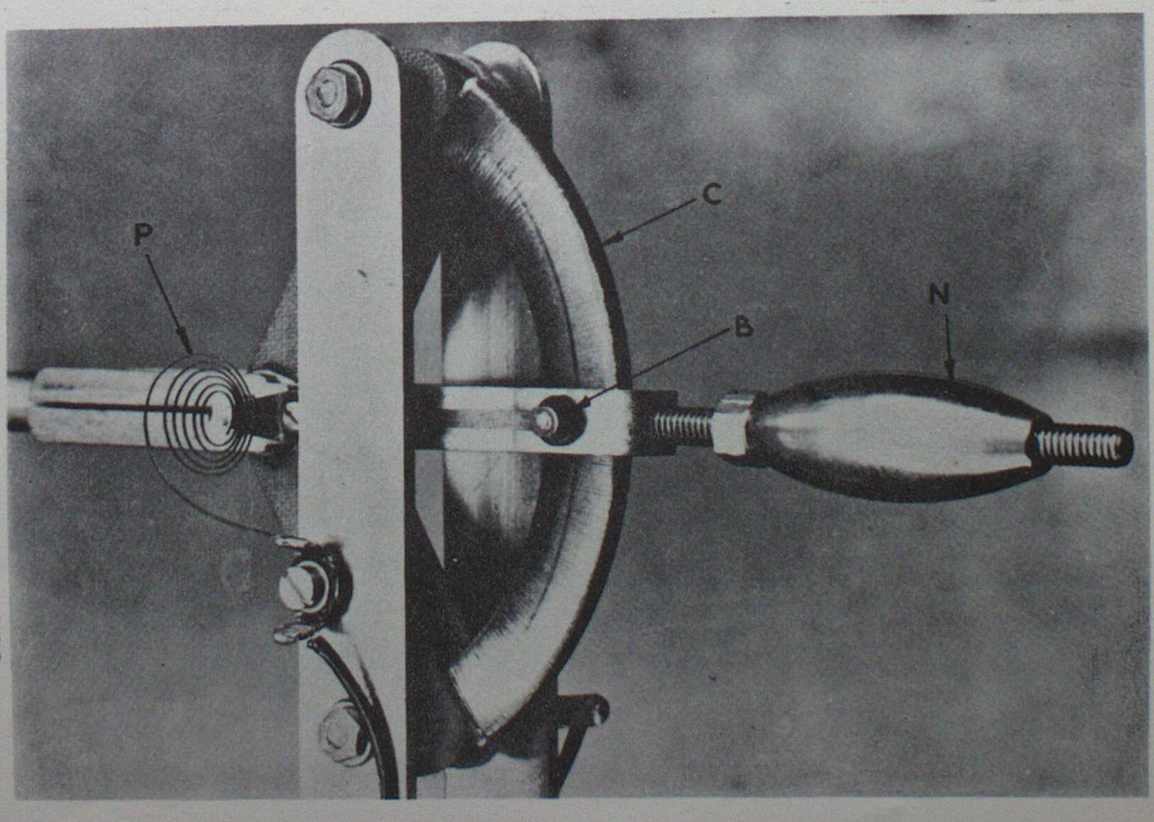


FIG. 2

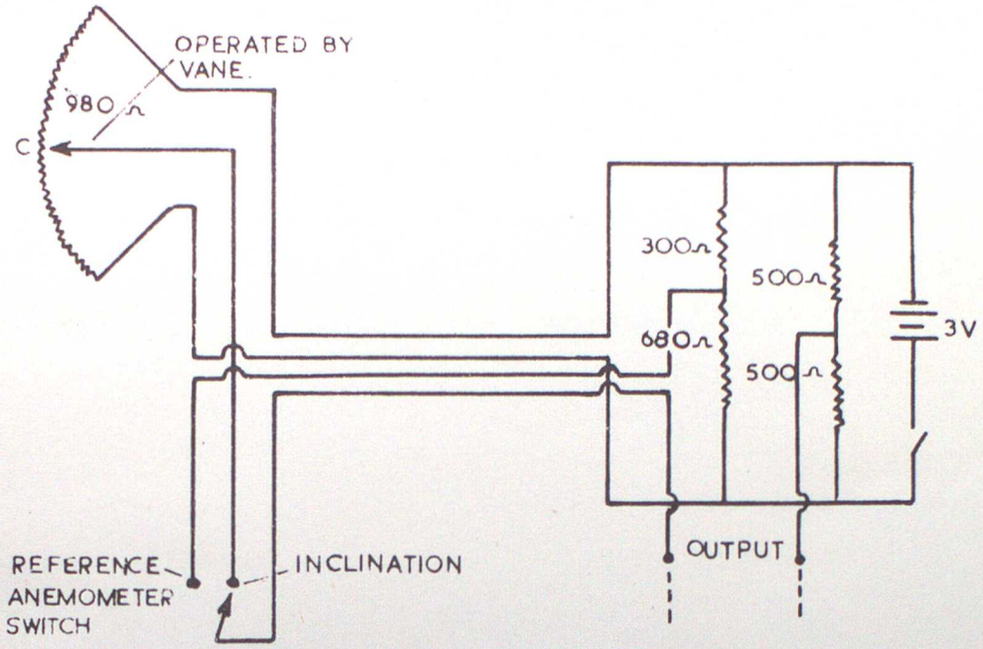


FIG. 3. GUSTINESS METER CIRCUIT THE OUTPUT IS APPROXIMATELY 0.03 VOLTS PER DEGREE.

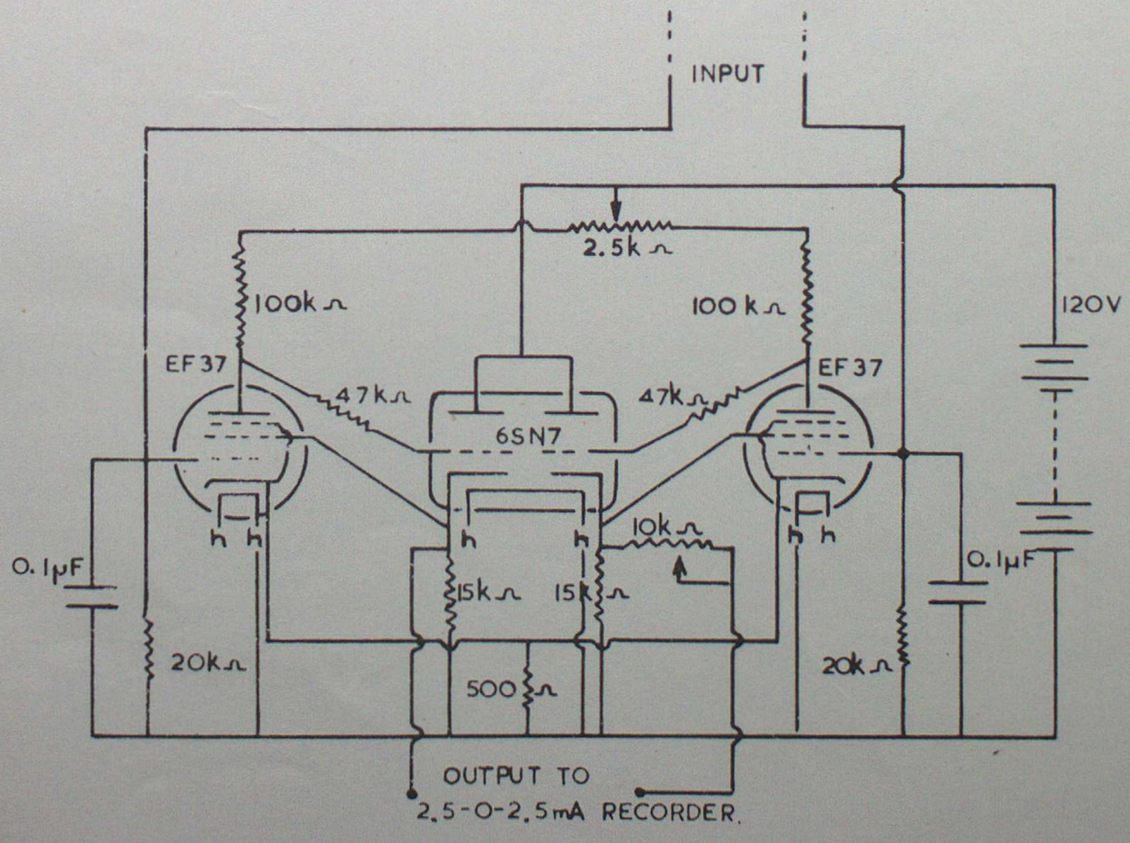
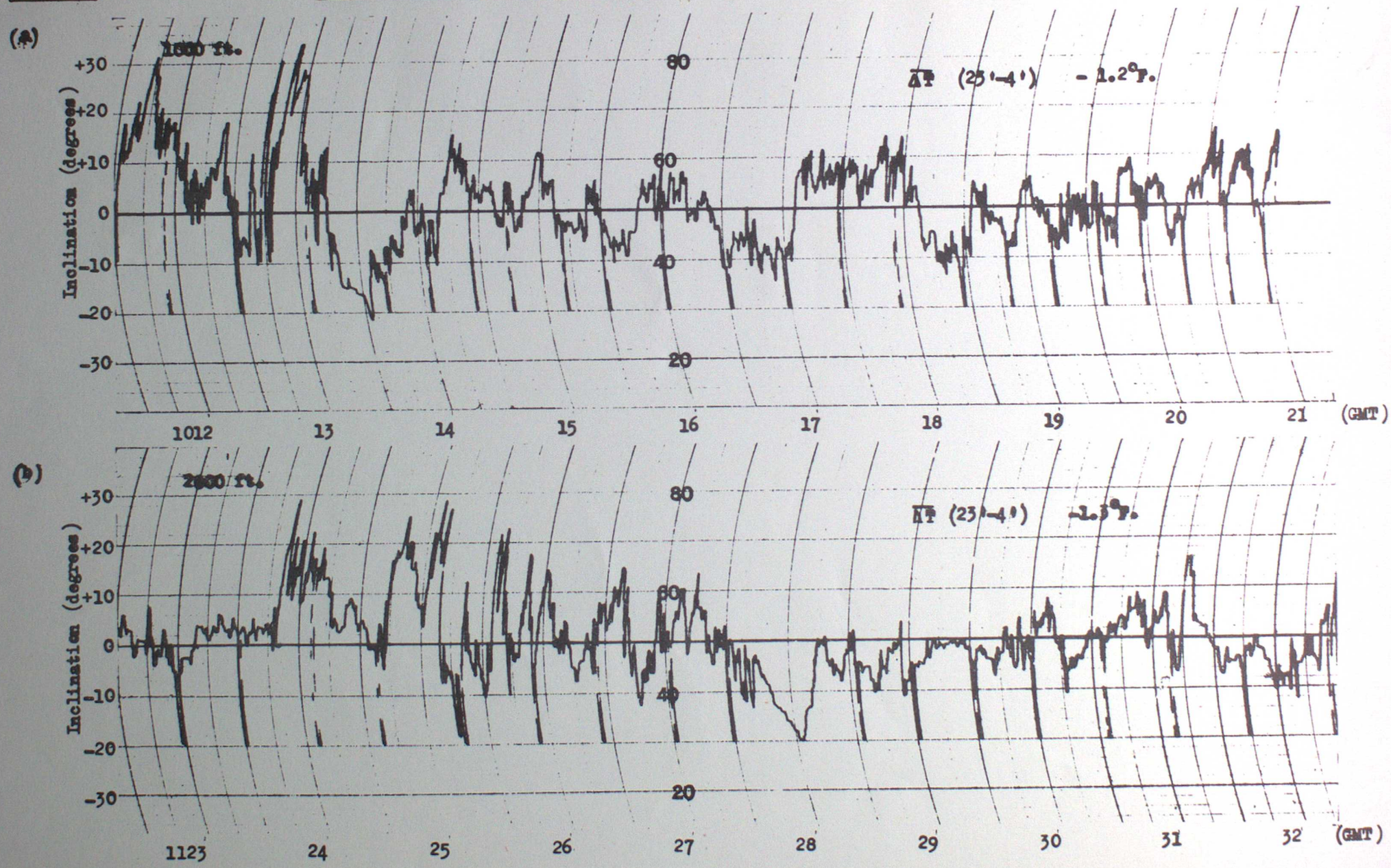


FIG. 4. CIRCUIT OF D.C. AMPLIFIER. VALVE HEATERS (h) ARE FED FROM A COMMON 6V ACCUMULATOR.

Figure 5 SAMPLE RECORDS AT 1000 ft. AND 2000 ft. ON 29 SEPT. 55.



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SAMPLE GUSTINESS RECORDS ON 13 OCT. 55.
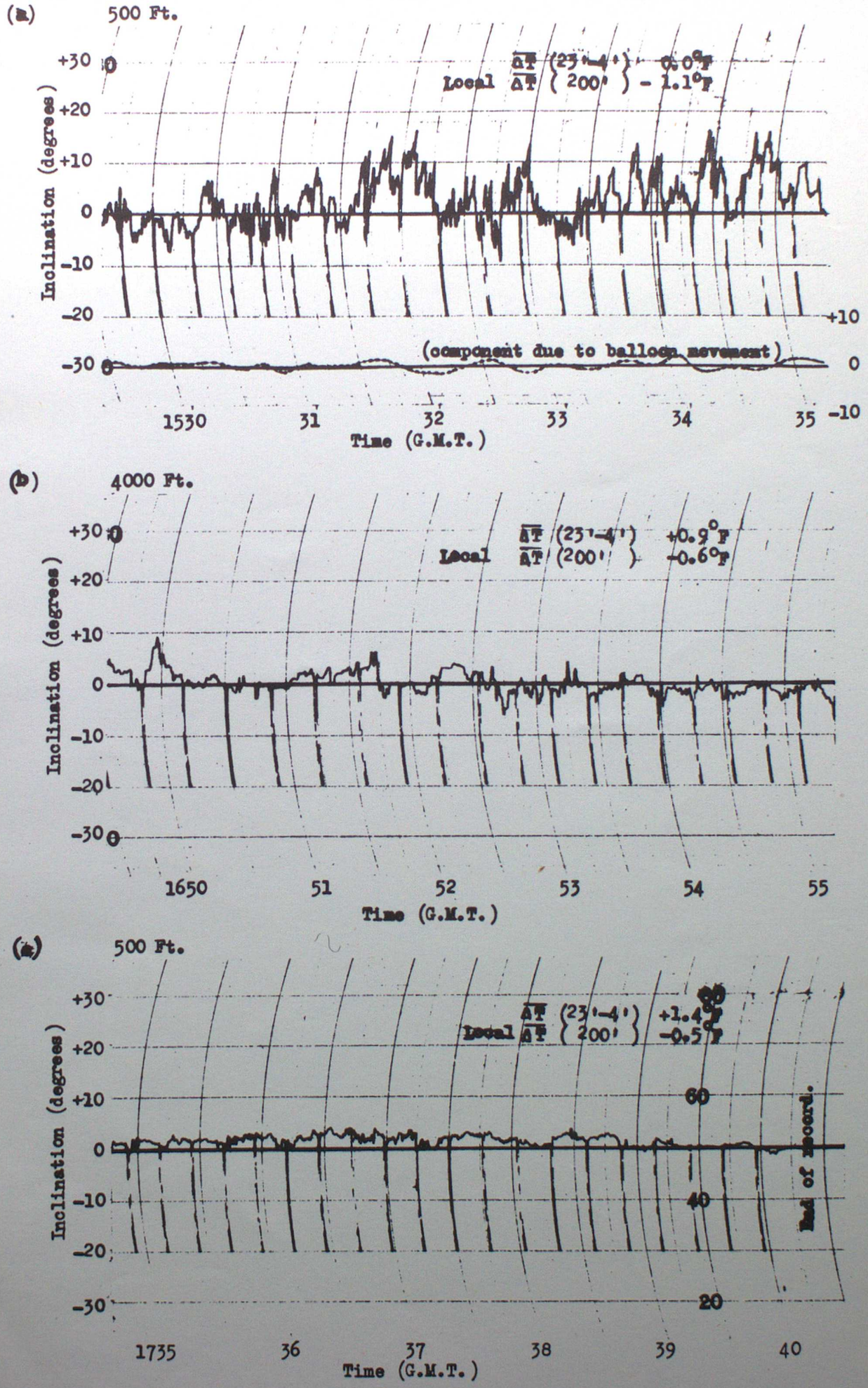
Figure 6.